

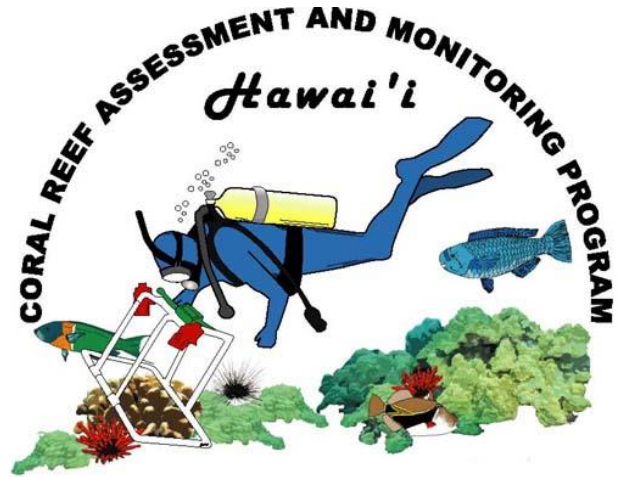
# **Hanauma Bay Biological Carrying Capacity Survey 2023/2024 Semi Annual Report**

For:

**City and County of Honolulu  
Parks and Recreation Department  
Hanauma Bay Nature Preserve  
Honolulu, Hawai'i**

Location:

**100 Hanauma Bay Road  
96825**



Prepared for:

**City and County of Honolulu: Parks and Recreation  
Hawai'i Board of Land and Natural Resources**

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## Executive Summary

During the 2023/2024 Biological Carrying Capacity semiannual report period from 1 June, 2023 through 31 October, 2023, all project work plan tasks were completed. This study looked at aspects of the biological capacity of the Hanauma Bay Nature Preserve. Water temperature measurements were recorded in all sectors of the inner reef flat. Bleaching surveys were conducted along preset transects and compared to temperatures in each sector to determine if observed bleaching was correlated with high ocean temperatures. Water clarity was measured and compared to the visibility prior to and during the COVID pandemic to determine how water clarity has shifted from change in visitor counts. Fish transects were conducted along preset transects to determine abundance and biomass in the Bay. Monk seal and green turtle abundance was recorded to better understand their population as it relates to visitor activity. In addition, a species archive was compiled containing photos and information of marine species that are found in the Bay to be used as an educational tool for visitors.

Water temperature measurements were collected temperature loggers from March-August 2023. Temperature fluctuations were minimal between sites. Overall temperature at Hanauma Bay ranged from 23.7 °C in April 2023 to 28.7°C in July 2023, with an overall mean temperature across all four sites at 26.0 °C. The maximum (28.7 °C) and the minimum (23.7 °C) temperatures occurred in the Backdoor and Witches Brew sectors. Temperatures did not exceed the coral bleaching threshold during this time period.

Water clarity was measured on the inner reef flat of the Bay using a secchi disk across three days encompassing two months. Water clarity in 2023 was found to be lower when compared to both the closed days in 2018 and during the COVID closure in 2020. This may be due to higher wave energy during surveys. Water clarity surveys during days open to the public will be conducted later in the year for the annual report in May 2024.

Fish transects to record species abundance and biomass were conducted in the inner reef flat of the Bay. Surgeonfishes (Acanthurids) were the most abundant family, with the brown surgeonfish, *ma'i'i'i* (*Acanthurus nigrofuscus*) the most abundant species. Chubs (Kyphosidae) comprised the highest biomass overall in the Bay with the Lowfin chub, *nenu* (*Kyphosus vaigiensis*) the species with the highest biomass. Across the Bay, herbivores are the dominant consumers of the reef. Approximately 24% of fishes were endemic to Hawai'i which is consistent with the state average of 25%.

Monk seal and green turtle abundance were recorded to add to previous data of population size in the HBNP. Sightings of monk seals and green turtles were uncommon during survey periods. Over a four-month period, there were a total of six green turtles and only one monk seal observed. Monk seals and green turtles will continue to be counted during field days with data included in the annual report.

A species archive was developed to describe all species found at the HBNP to augment Sea Grant's photo archive for educational purposes. Detailed archives separated by biological groups were created to focusing on fishes, invertebrates, and seaweeds to provide in depth identification tools for snorkelers. The master species archive contains species in all previously listed categories for faster and easier identification. These archives are currently available as links to a google document and can be added to the HBNP website

## **Introduction**

The Hanauma Bay Nature Preserve (HBNP) is the most popular snorkeling experience for visitors in Hawai'i. Since its establishment as an MLCD in 1967, the Bay has seen millions of annual visitors with the highest recorded number in the 1980s. The level of human use an area can withstand while still maintaining sustainability is often referred to as the carrying capacity of the area. However, with the management of any conservation area, a balance between recreation and ecosystem health is vital. Thus, our carrying capacity studies were designed to incorporate many diverse aspects of carrying capacity: biological, social, and physical.

In 2021, the first full year open following the pandemic, the HBNP recorded only 386,054 annual visitors, approximately 1,500/day (two closed days/wk omitted in calculations). This change is less than half the admittance prior to the pandemic where the Bay saw 842,439 annual visitors (3,000/day). Based on box office counts available to the public on the City & County website, there have been 365,744 annual visitors (1,400/day) in 2022. 2023 is predicted to similarly have 376,417 annual visitors. Carrying capacity studies have been conducted at Hanauma Bay in the past, examining capacity during differing population densities of the Bay's operation (Brock and Kam 2000, Wanger 2001). High tourism use leads to environmental degradation. Crowding and the physical effects of human use can be detrimental to marine resources. Trampling on the nearshore reef can cause habitat destruction and coral mortality. High visitor use may also result in changes in fish diversity. .

The last biological carrying capacity study conducted at Hanauma Bay was in 2020 during the COVID 19 pandemic (Severino et al. 2021). This study occurred during the COVID closure of the HBNP and examined the immediate results of an anthropause on the environment (Bates et al. 2022). The data collected during this study offers an initial perspective into how the Bay has changed following the COVID pandemic. While previous studies have looked into the physical (Graham et al. 2023) and social (Graham et al. 2022) carrying capacities of the Bay, the biological carrying capacity focuses on the health of the marine ecosystem at the HBNP.

The previous biological carrying capacity study was carried out across a three-year period. The first year placed coral skeletons throughout the inner reef flat of the HBNP to determine how breakage relates to anthropogenic activity by sector within the Bay. Coral skeletons showed higher breakage in high use areas (Keyhole) compared to lower use areas such as Witches Brew

(Severino et al 2019). This study also looked into anthropogenic effects on water clarity and sediment accumulation on the reef. The first year of the Hanauma Bay Biological Carrying Capacity study found coral breakage and sediment accumulation increased with increasing visitor presence while water clarity decreased.

The second year focused on fish surveys and compared them to historical fish surveys when fish feeding was still allowed at Hanauma Bay. The comparison of surveys determined shifts in the dominant families between these two time periods. During fish feeding, the most dominant families were chubs (Kyphosidae, *nenuke*), mullet (Mugilidae), flagtails (Kuhliidae, *āholehole*), filefish (Monacanthidae), hawkfish (Cirrhitidae), boxfishes (Ostraciidae), and cornetfish (Fistulariidae). Subsequent to fish feeding, families in greater abundance were wrasses (Labridae), jacks (Caranididae), Tangs (Acanthuridae), parrotfishes (Scaridae) and snappers (Lutjanidae) (Severino et al. 2020).

The third year of the Biological Carrying Capacity occurred at the onset of the COVID pandemic. Surveys during this time point included a continuation of fish biomass and abundance surveys, water clarity, and sediment accumulation surveys. Green turtle and monk seal presence were recorded during survey days. This year's study found the Bay was 56% clearer during the COVID closure than on days open to the public in 2018, and 8.9% clearer during the COVID closure than on Tuesdays in 2018 when closed to the public. Monk seals showed a 44% increase in the presence during the closure (non-significant) when compared to before the closure. After the Bay was reopened to the public at 25% capacity, the abundance of monk seals significantly decreased by 87%. The perspective of this Carrying Capacity was heavily based on anthropogenic impacts and recovery.

**Projected scope of work details from project work plan**

<b>Semi Annual Report</b>	<b>Task/Activity</b>	<b>Results</b>
May - October	<p>Task 1: Annual water temperature measurements</p> <ul style="list-style-type: none"> <li>· Temperature loggers deployed and replaced</li> </ul> <p>Task 2: Secchi water clarity measurements</p> <p>Task 3: Fish abundance and biomass</p> <p>Task 4: Monk seal and green turtle abundance</p> <p>Task 5: Coral bleaching surveys</p> <ul style="list-style-type: none"> <li>· Bleaching surveys conducted along set transects</li> </ul> <p>Task 6: Species archive database</p> <ul style="list-style-type: none"> <li>· Compile database of all marine species found at Hanauma Bay</li> </ul>	<p>Task 1: Loggers deployed 3/14/23, collected 8/22/23, and redeployed to be collected spring 2024</p> <p>Task 2: Secchi measurements taken in all sectors of the Bay across three time periods</p> <p>Task 3: Fish transect surveys completed at each of the two transects per sector</p> <p>Task 4: Monitored presence of seals and turtles observed during survey days</p> <p>Task 5: Bleaching surveys completed at inner reef of the Bay</p> <p>Task 6: Species archive completed for fishes, invertebrates, and algae.</p>
<b>Annual Report</b>	<b>Task/Activity</b>	<b>Results</b>
October-May	<p>Task 7: Coral Reef Assessment and Monitoring Program (CRAMP) surveys</p> <p>3m and 10m</p>	<p>Task 7:</p> <ul style="list-style-type: none"> <li>· CRAMP to be completed in winter 2023.</li> </ul>

## Detailed descriptions and outcomes of work activities

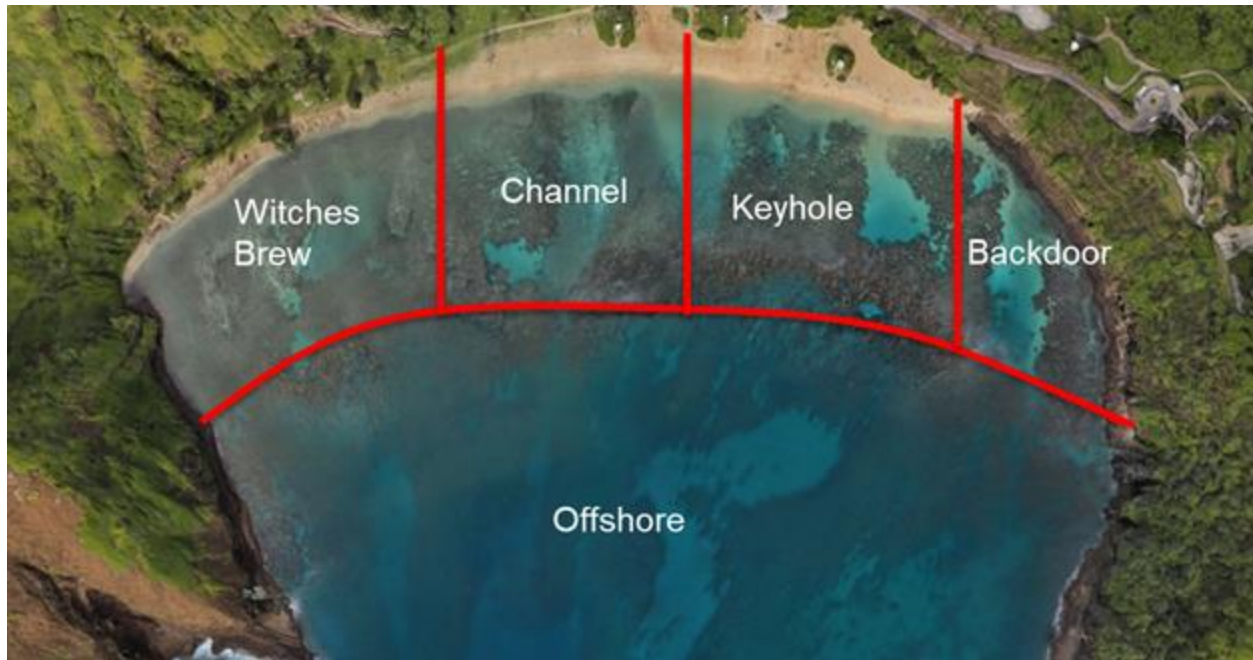
### Task 1: Water temperature measurements

#### *Temperature and Monitoring*

##### **Methods**

Temperature is monitored using Onset© data loggers with an accuracy of  $\pm 0.53^{\circ}\text{C}$  and range of  $-20^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ . Loggers are calibrated prior to placement by immersion in water baths outside natural ranges ( $0^{\circ}\text{C}$  to  $40^{\circ}\text{C}$ ). A certified thermometer and water bath are used to standardize loggers during calibration. Loggers are inconspicuously placed on the reef in discrete concrete houses wedged in rock crevices to prevent sun exposure and extraneous irradiance (Bahr et al. 2015). Temperature gauges are programmed to record temperature at hourly intervals and downloaded quarterly in the field using HOBOWare Pro. In March 2023, four temperature loggers were installed in all major sectors, Keyhole, Witches Brew, Channel, and Backdoor (Fig. 1) of the inner reef flat to encompass monitoring during the warmest summer months. Data loggers were replaced and downloaded in August 2023 and replaced for continuous data recording. An error occurred in the Channel temperature logger upon download and creating a gap in data from July 2022 to February 2023.

Overall temperature at Hanauma Bay ranged from  $23.7^{\circ}\text{C}$  in April 2023 to  $28.7^{\circ}\text{C}$  in July 2023, with an overall mean temperature across all four sites at  $26.0^{\circ}\text{C}$ . The highest annual mean temperature was observed at Witches Brew, at  $26.0^{\circ}\text{C}$ , and the lowest annual mean temperatures were observed at Keyhole and Backdoor, at  $25.95^{\circ}\text{C}$  and  $25.94^{\circ}\text{C}$  respectively, due to the circulation patterns on the inner reef flat (Rodgers et al., 2017). Mean temperature at Keyhole ranged from  $25.2^{\circ}\text{C}$  in April 2023 to  $27.0^{\circ}\text{C}$  in August 2023 with a monthly fluctuation of  $4.0^{\circ}\text{C}$  (Fig. 2). Mean temperature at Channel ranged from  $25.3^{\circ}\text{C}$  in April 2023 to  $27.0^{\circ}\text{C}$  in August 2023 with a mean fluctuation of  $3.5^{\circ}\text{C}$  (Fig. 2). Mean temperature at Backdoor ranged from  $25.3^{\circ}\text{C}$  in March 2023 to  $27.0^{\circ}\text{C}$  in August 2023 with a mean fluctuation of  $3.6^{\circ}\text{C}$  monthly (Fig. 2). Mean temperature at Witches Brew ranged from  $25.4^{\circ}\text{C}$  in March 2023 to  $27.0^{\circ}\text{C}$  in August 2023 with a mean monthly fluctuation of  $3.1^{\circ}\text{C}$  (Fig. 2). Annual temperatures are shown in Figure 2.

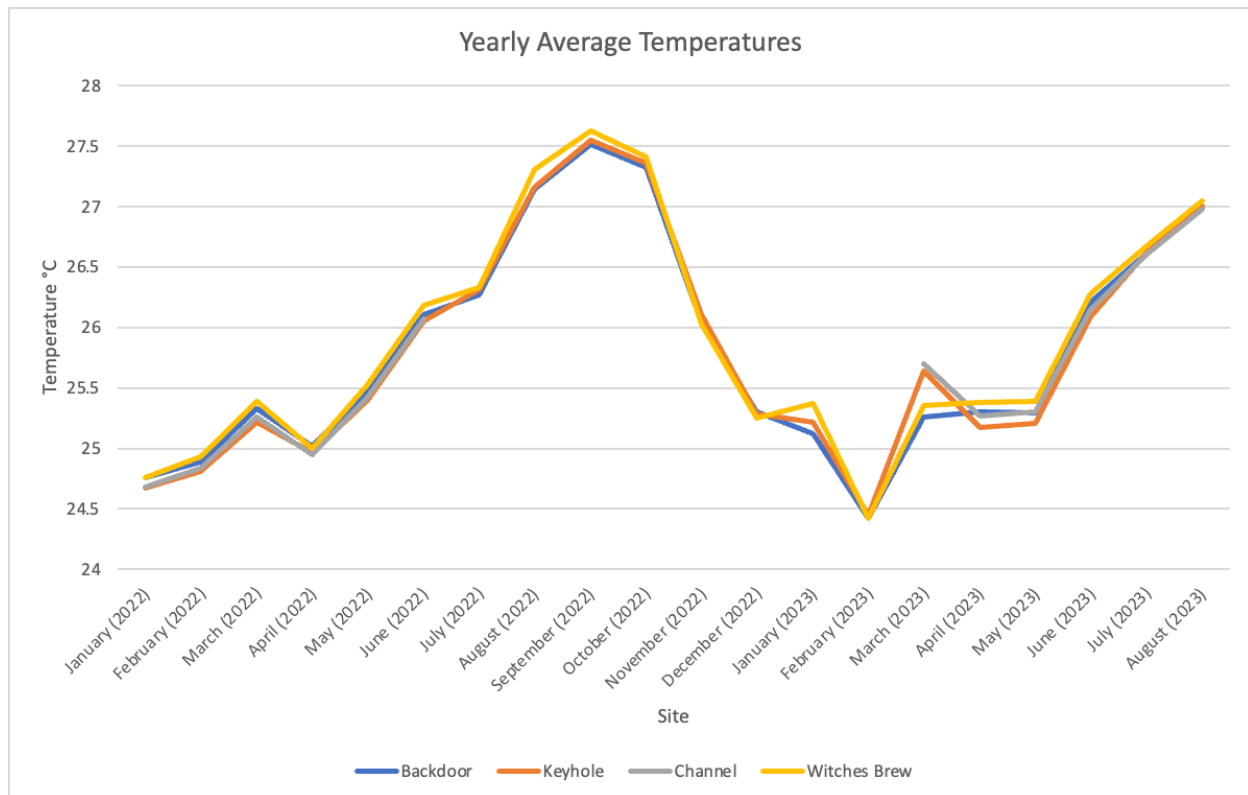


**Figure 1.** Delineations on the shallow reef flat at the Hanauma Bay Nature Preserve using commonly used local names.

#### *Temperature thresholds*

Bleaching has been documented as a sign of stress from temperature, sediments, nutrients, or other factors (Rodgers et al. 2017). Jokiel and Coles (1990) determined the bleaching threshold for Hawaiian corals at 29-30 °C, a 1-2 °C increase above upper summer maximums (Jokiel 2004). However, coral bleaching is not a direct response to temperature. Ocean circulation patterns, irradiance intensity, cloud cover, rainfall, wind speed and direction, water clarity, and duration and intensity can determine impacts of bleaching.

The bleaching threshold of corals is a 1-2°C increase above their summer maximum temperature, which is usually around 29-30°C in Hawai'i (Jokiel and Coles 1977). The lower temperature threshold for Hawaiian corals is 18°C. The majority of the temperatures observed in the Bay over the sampling period, March 2023 to August 2023, did not exceed the thresholds for bleaching. The temperatures observed thus far are not indicative of acute thermal stress as all temperatures were below 29 °C. Temperature values collaborated with bleaching surveys conducted on 22, August 2023 that found minimal bleaching.



**Figure 2.** Temperatures within all four sites in the inner reef flat at Hanauma Bay from January 2022 to August 2023.

## Task 2: Water Clarity

### **Methods**

Secchi disk water clarity measurements were taken within the four sectors of the HBNP to determine water visibility across time and environmental conditions among sectors. Surveys were conducted on three days over two months between July and August of 2023 on days closed to the public on the east and west sides of each sector. During surveys conducted over five months from June and October of 2018, water visibility data was collected on six days closed to the public (8 observations per day) and 18 days open to the public (8 observations per day). During the COVID-19 closure, secchi disk measurements were repeated in the absence of visitors on 24 dates (4 observations per day) over a period of nine months between April and December 2020. Hanauma Bay reopened to the public on December 2nd, with limited capacity. Secchi disk measurements were collected on three days in December and three days in January (6 days, 4 observations per sector per day). Data was used to compare spatial and temporal water visibility.

To measure secchi disk water clarity, surveyor one holds the disk while surveyor two swims away with the connected transect tape until the white secchi disk is no longer visible. Surveyor two records the distance at which the disk is no longer visible. The surveyor swims away from

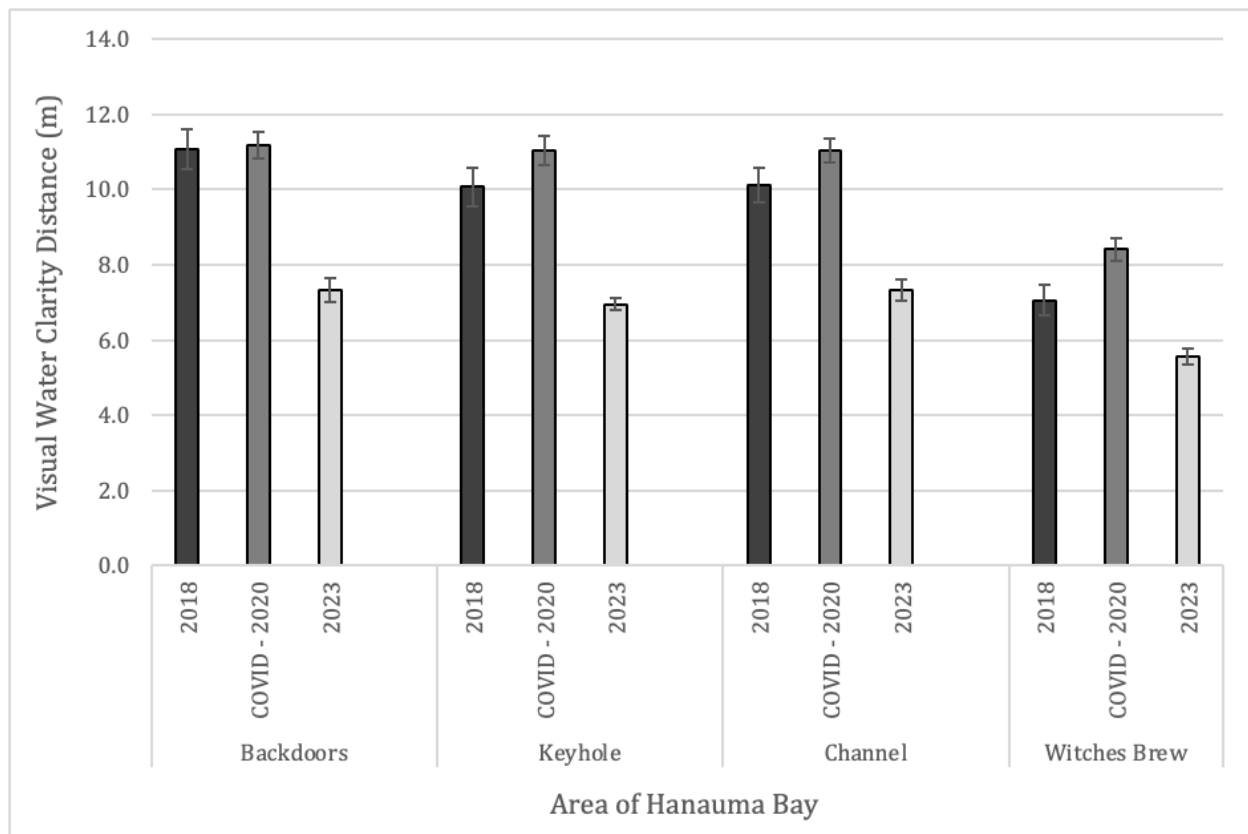


the disk and waits for 30 seconds before swimming toward the disk and stopping to record the distance at which the disk is again visible. To reduce error from factors other than visitor impacts, environmental data on wind speed and direction is acquired from the National Oceanic and Atmospheric Administration (NOAA) station 1612340 in Honolulu, HI. Wave height and direction data were acquired from the closest NOAA buoy 51202 off the windward side of O‘ahu at Mokapu Point, Kāne‘ohe.

## **Results and Discussion**

Closed days in 2023 had lower average water clarity measurements than on closed days in 2018 (Pairwise Wilcoxon Test,  $p < 0.001$ ) and during the COVID-closure (Pairwise Wilcoxon Test,  $p < 0.001$ ) (Table 1). In all sectors, average water clarity on closed days in 2023 was lower than on closed days in 2018 and during the COVID-closure (Fig. 3). Overall average water clarity in the Bay during closed days in 2018 was  $2.8 \pm 0.9$  meters clearer than water clarity on days closed to the public in 2023, and  $3.6 \pm 0.5$  meters clearer during the COVID-closure than on days closed to the public in 2023 (Fig. 3). The contrast of water quality measurements from 2018, on days closed, to 2023 on days closed was notably lower. This may be attributed to lower box office counts, fewer surveys, or differences in wind, tides and/or wave energy.

Environmental parameters such as wind direction and speed, wave direction and speed, tidal flux and swell are influential drivers in water clarity on reefs. Water clarity has also been shown to be influenced by the number of visitors in each sector (Hanauma Bay Carrying Capacity Report 2018/19). However, box office numbers were not included as an influential factor on water clarity in this report as water clarity measurements being considered were only taken on days closed to the public, and the Hanauma Bay Carrying Capacity Report 2020/21 data suggested sediments were not suspended in the water column for longer than 24 hours. During closed days in 2023, the most influential parameters on water quality were tidal coefficient, wind speed, wind direction, and wave direction (Table 1). The negative tidal coefficient correlation (correl.coef: -0.27,  $p < 0.01$ ) suggests that as tides decrease, water clarity increases at Hanauma Bay.



**Figure 3.** Bar graph depicting average visual water clarity distances for each sector of Hanauma Bay for 2018, 2020, and 2023 on days closed to the public. Visual water clarity distance was measured using the Secchi Disk method. 2018 data was averaged over June and October. 2020 data was taken between April and May during the COVID closure. 2023 data represents observations between July and August. Standard error bars represent  $\pm 1$  SE. All time periods were statistically different from one another.

**Table 1.** Results of a non-parametric Kendall's tau correlation test between secchi distance and environmental variables (\* indicates a significant correlation ( $p < 0.05$ )).

		<b>Tidal Coefficient</b>	<b>Wind Speed</b>	<b>Wind Direction</b>	<b>Wave Height</b>	<b>Wave Direction</b>	<b>Mean Wave Period</b>
<b>Closed 2018</b>	<b>Correlation Coefficient</b>	-0.178*	-0.168*	0.227*	-0.373*	-0.373*	0.036
	<b>Sig. (2-tailed)</b>	<0.001	<0.01	<0.001	<0.001	<0.001	0.467
<b>COVID 2020</b>	<b>Correlation Coefficient</b>	0.174*	0.071*	-0.092*	-0.186*	0.062	-0.120*
	<b>Sig. (2-tailed)</b>	<0.001	<0.05	<0.01	<0.001	0.078	<0.01
<b>Closed 2023</b>	<b>Correlation Coefficient</b>	-0.270*	0.270*	0.270*	0.143	-0.270*	0.143
	<b>Sig. (2-tailed)</b>	<0.01	<0.01	<0.01	0.100	<0.01	0.100

### Task 3: Fish Abundance and Biomass Surveys

#### **Methods**

A modified visual transect (line/belt/strip) (Brock 1954) (species abundance methodology) is employed to quantify fish communities. The fish surveyor spools out the 82 ft (25 m) transect line while recording, species, size (total length [TL] in centimeters [cm]) and the number of individual fishes to 7 ft. (2 m) on each side of the 13 ft. (4 m total width) transect line. This eliminates changes in fish behavior and allows fishes to equilibrate from previous activity in contrast to laying a transect prior to the survey. All transects are perpendicular to shore. The surveyor records on a slate, equipped with underwater writing paper. All fishes within the linear transect from the bottom to the surface are recorded.

Biomass estimates are derived through total length estimated to the nearest cm in the field and converted to biomass estimates (kg/m<sup>2</sup>) using length-weight fitting parameters. In estimating fish biomass from underwater length observations, most fitting parameters are obtained from the Hawai'i Cooperative Fishery Research Unit (HCFRU) consistent with previous analyses. Additionally, locally unavailable fitting parameters are obtained from Fishbase ([www.fishbase.org](http://www.fishbase.org)) whose length-weight relationship is derived from over 1,000 references. The general trend for a 10 cm fish of the common fusiform shape should be approximately 10 g. Any gross deviations are replaced with values from the alternate source.

Trophic categories include herbivores, invertebrate feeders, zooplanktivores, and piscivores. These categories are similar to the functional groups used by Friedlander (2018). Herbivorous

fishes diet consists primarily of algae, zooplanktivores feed in the water column on zooplankton, invertebrate feeders are described as fishes feeding on small benthic invertebrates and include corallivores that feed exclusively on corals, and piscivores that eat fishes and invertebrates. Friedlander (2018) is based on data that is a compilation of over 25 datasets containing greater than 25,000 surveys collected between 2000 and 2018. The Hawai'i Monitoring and Reporting Collaborative (HIMARC) is a consortium of managers and researchers throughout the Hawaiian Islands that collectively contribute monitoring and assessment data to the largest database for fishes in Hawai'i.

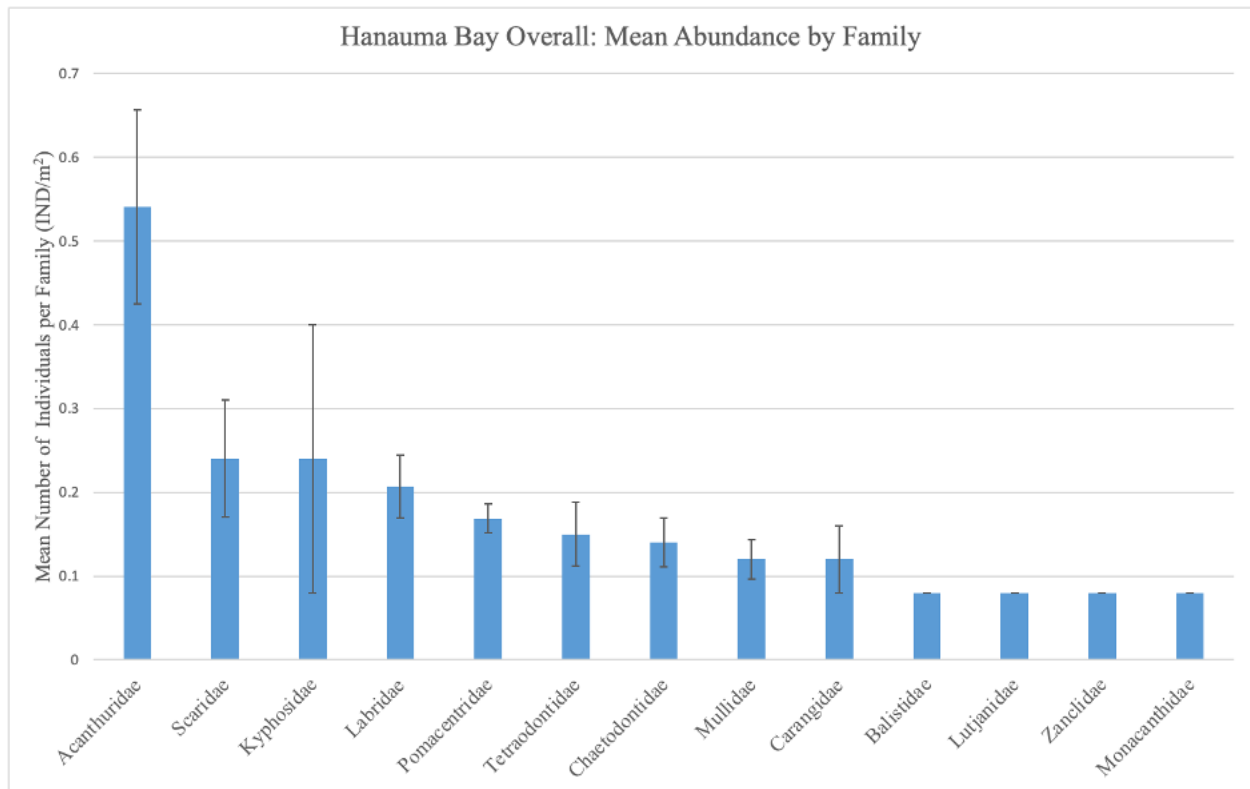
Diversity was calculated using the Shannon-Weiner diversity index  $H' = \sum_{i=1}^S p_i \ln p_i$ . Where S is the total number of species present, and  $P_i$  is the relative cover of ith species. Biodiversity is an important indicator of change in an ecosystem. A diverse environment is a healthy system that can continue functioning. Negative changes to biodiversity indicate a decline in ecosystem function and health.

## Results

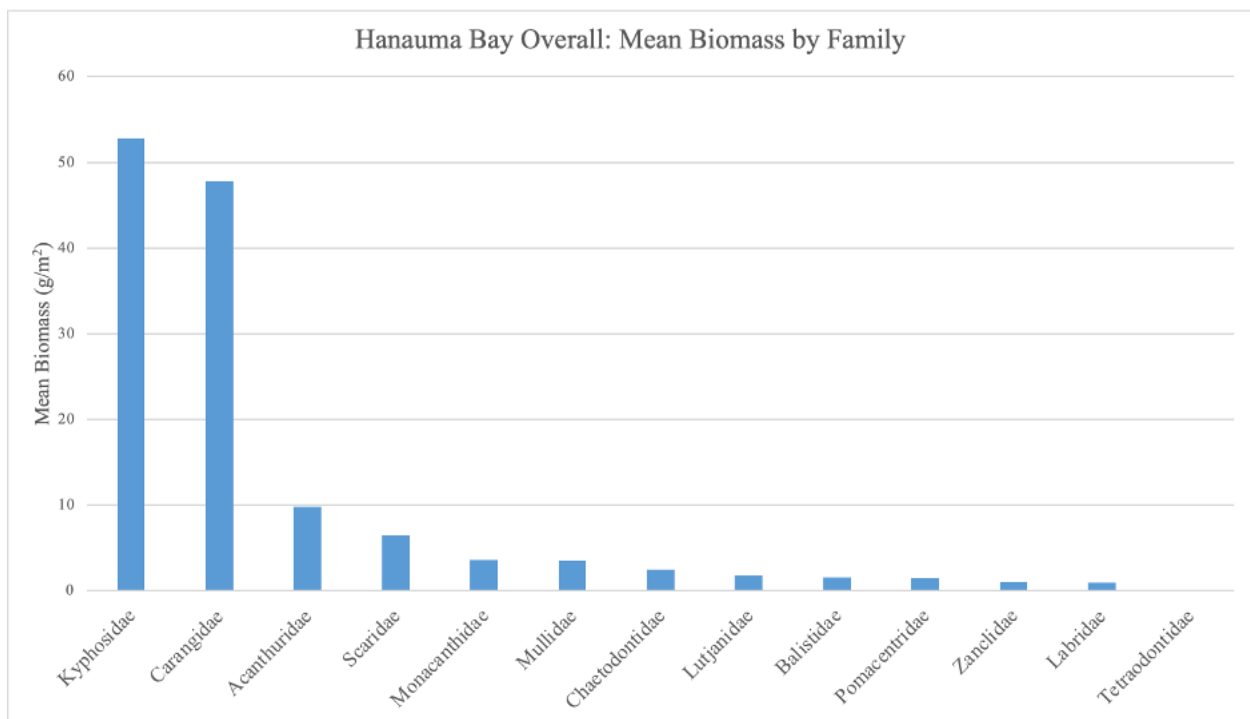
The following quantitative assessment summarizes the fishes that were present on the inner reef flat of the HBNP in July 2023.

### Overall Abundance and Biomass

Approximately a quarter of the individual fishes present ( $0.54 \pm 0.12$  individuals/m<sup>2</sup>) are within the family of surgeonfishes (Acanthuridae) while they comprise only 7% of the total biomass ( $9.84 \pm 1.58$  g/m<sup>2</sup>) (Fig 4 and 5). Parrotfishes (Scaridae) and Chubs (Kyphosidae) comprise the second highest abundance ( $0.24 \pm 0.07$  individuals/m<sup>2</sup> and  $0.24 \pm 0.16$  individuals/m<sup>2</sup> respectively). Chubs have the highest overall biomass ( $52.84 \pm 44.12$  g/m<sup>2</sup>) while Parrotfishes have the fourth highest biomass ( $6.42 \pm 1.79$  g/m<sup>2</sup>) (Fig 9). Wrasses (Labridae) contribute greatly to abundance ( $0.20 \pm 0.03$  individuals/m<sup>2</sup>) but do not contribute substantially to the total biomass ( $0.95 \pm 0.23$  g/m<sup>2</sup>). This difference in contribution is likely due to the small size of wrasses. The next four most abundant families, Damselfishes (Pomacentridae,  $0.17 \pm 0.01$  individuals/m<sup>2</sup> and  $1.49 \pm 0.49$  g/m<sup>2</sup>), Pufferfishes (Tetraodontidae,  $0.15 \pm 0.04$  individuals/m<sup>2</sup> and  $0.10 \pm 0.02$  g/m<sup>2</sup>), Butterflyfishes (Chaetodontidae,  $0.14 \pm 0.03$  individuals/m<sup>2</sup> and  $2.53 \pm 1.24$  g/m<sup>2</sup>), and Goatfishes (Mullidae,  $0.12 \pm 0.02$  individuals/m<sup>2</sup>, and  $3.47 \pm 0.31$  g/m<sup>2</sup>) collectively contribute approximately 25% of the total abundance and about 5% of the total biomass.



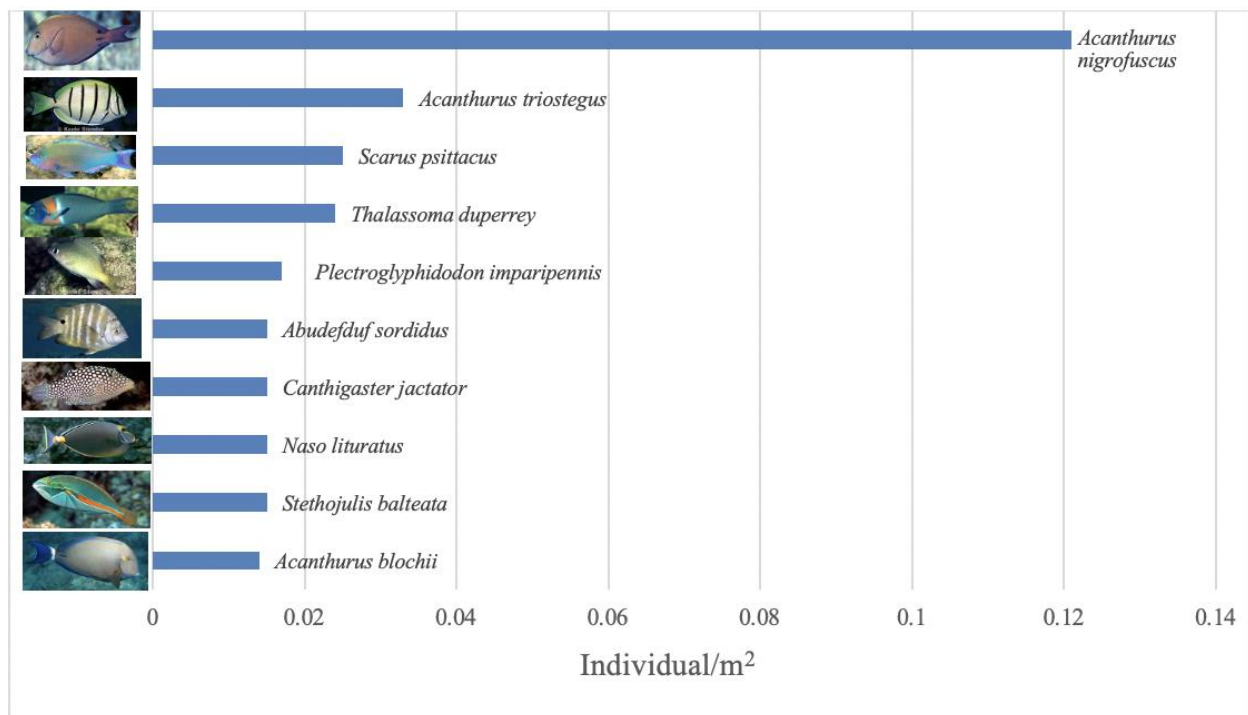
**Figure 4.** Hanauma Bay reef flat overall average abundance (individuals/m<sup>2</sup>) by fish family.



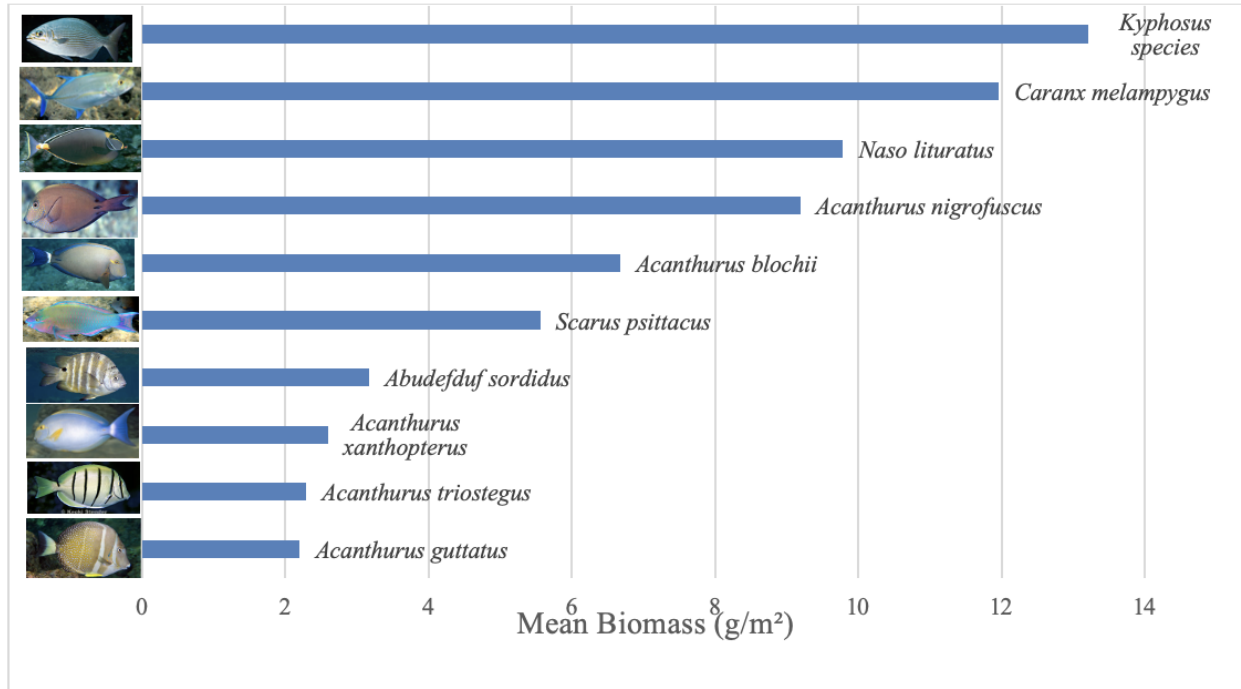
**Figure 5.** Hanauma Bay reef flat average biomass (g/m<sup>2</sup>) by fish family.

### Species Abundance and Biomass

The brown surgeonfish, *ma'i'i'i* (*Acanthurus nigrofuscus*) was the most abundant species (0.121 Ind/m<sup>2</sup>) and ranked fourth in biomass (9.19 g/m<sup>2</sup>) (Fig 6). The Lowfin chub, *nenue* (*Kyphosus vaigiensis*) had the highest biomass (13.21 g/m<sup>2</sup>) but did not rank in the top 10 most abundant species due to their large size (Fig 7). The convict tang, *manini* (*Acanthurus triostegus*) were the second most abundant species (0.033 ind/m<sup>2</sup>). The blue trevally, *'omilu* (*Caranx melampygus*) ranked second in overall biomass (11.96 g/m<sup>2</sup>) but did not rank high in abundance. Other species in high abundance include the Palenose Parrotfish, *uhu* (*Scarus psittacus*), the Saddle Wrasse, *hinalea* (*Thalassoma duperrey*), the Brighteye Damsel, *Plectroglyphidodon imparipennis*, the Blackspot Sergeant, *kupipi* (*Abudefduf sordidus*), the Hawaiian Whitespotted Toby (*Canthigaster jactator*), the Orangespine Unicornfish, *umaumalei* (*Naso lituratus*), the Belted Wrasse, *ōmaka* (*Stethojulis balteata*), and the Ringtail Surgeonfish, *pualu* (*Acanthurus blochii*). Biomass was additionally dominated by surgeonfishes (the Orangespine Unicornfish, the brown surgeonfish, the Ringtail Surgeonfish, the Yellowfin Surgeonfish (*Acanthurus xanthopterus*), the convict tang, the Whitespotted Surgeonfish, *'api* (*Acanthurus guttatus*) and the Palenose parrotfish.



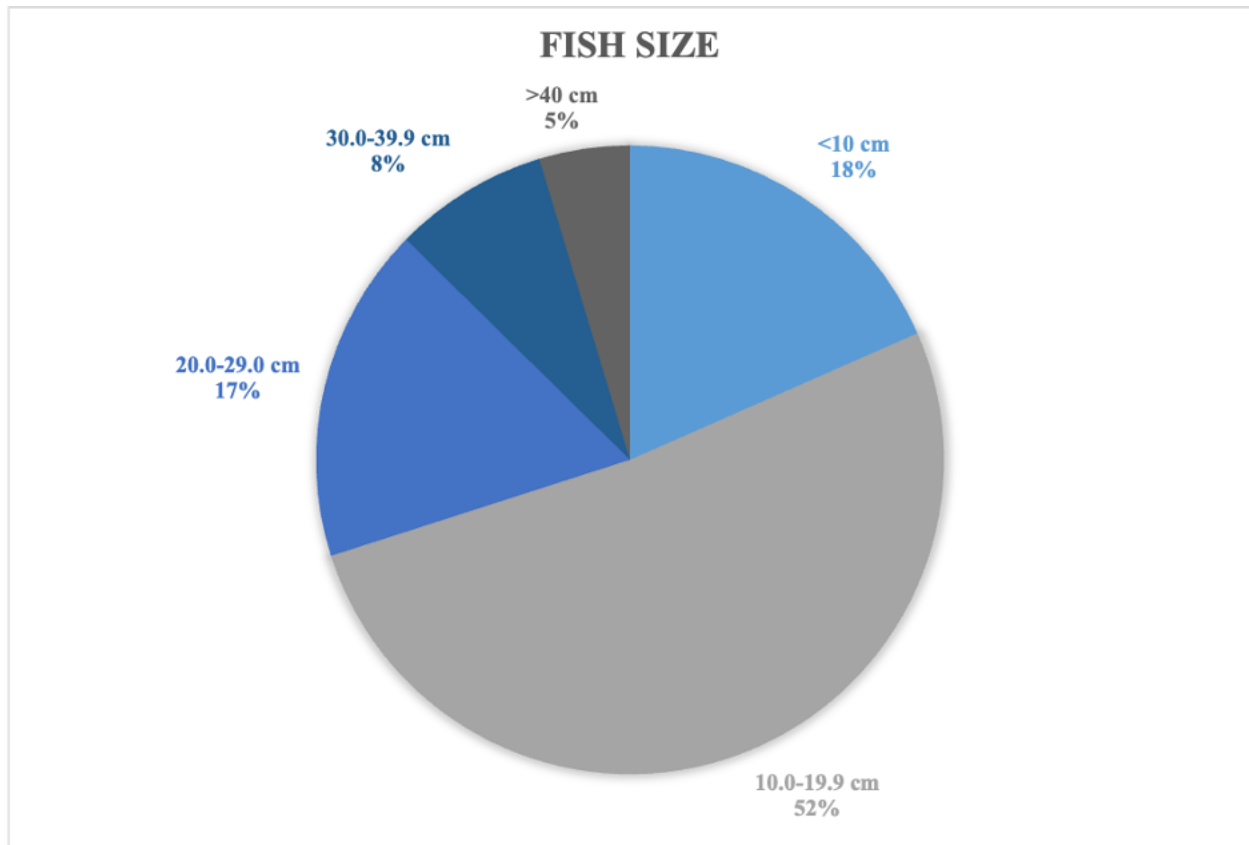
**Figure 6.** Hanauma Bay reef flat overall top 10 species by abundance (individual/m<sup>2</sup>). (marinelifephoto.com)



**Figure 7.** Hanauma Bay reef flat overall top 10 species by biomass (ind/m2).  
(marinelifephotography.com)

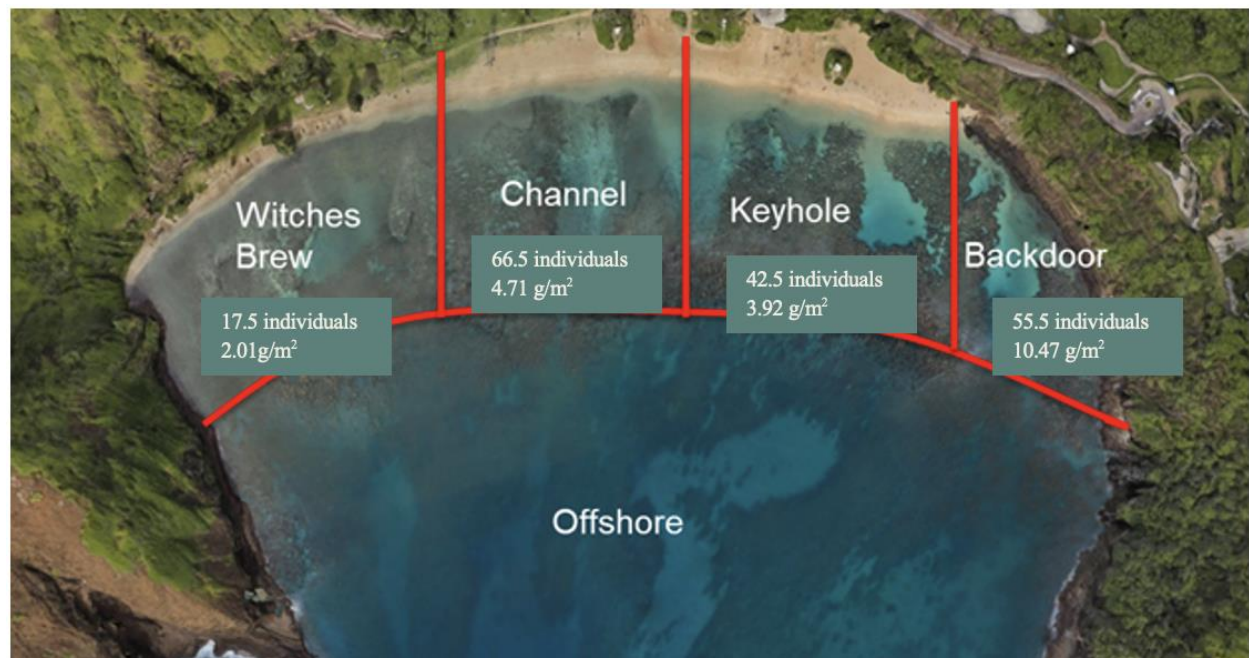
### Size Class

Recorded fishes were placed into the following five size classes: <10 cm (3.9 inches), 10.0-19.9 cm (3.9-7.8 inches), 20.0-29.9 cm (7.9-11.7 inches), 30.0-39.9 cm (11.8-15.7 inches), >40 cm (15.7 inches). The greatest number of fishes (52%) were between 10.0 and 19.9 cm. Fish under 10 cm and between 20.0 and 29.9 comprised 18% and 17% of observed fishes respectively (Fig 8).



**Figure 8.** Pie chart showing percentage of observed fishes in each of five size classes.

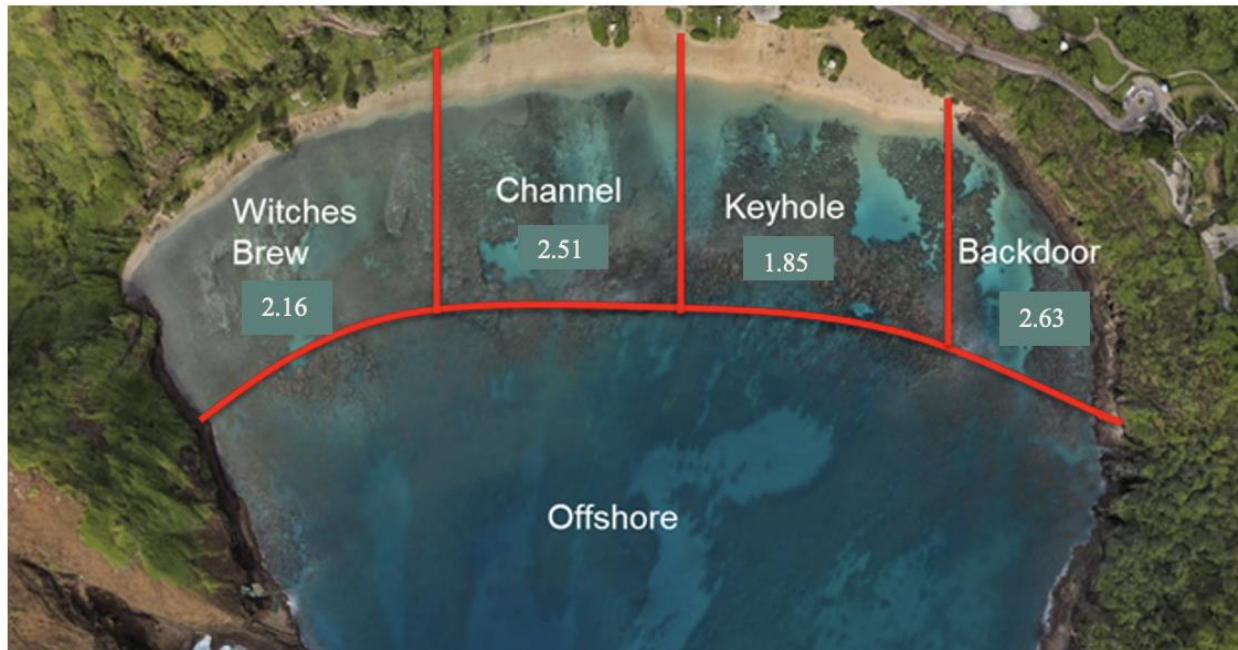
### Breakdown by sector



**Figure 9.** Average fish abundance and biomass at each sector on the Hanauma Bay reef flat.

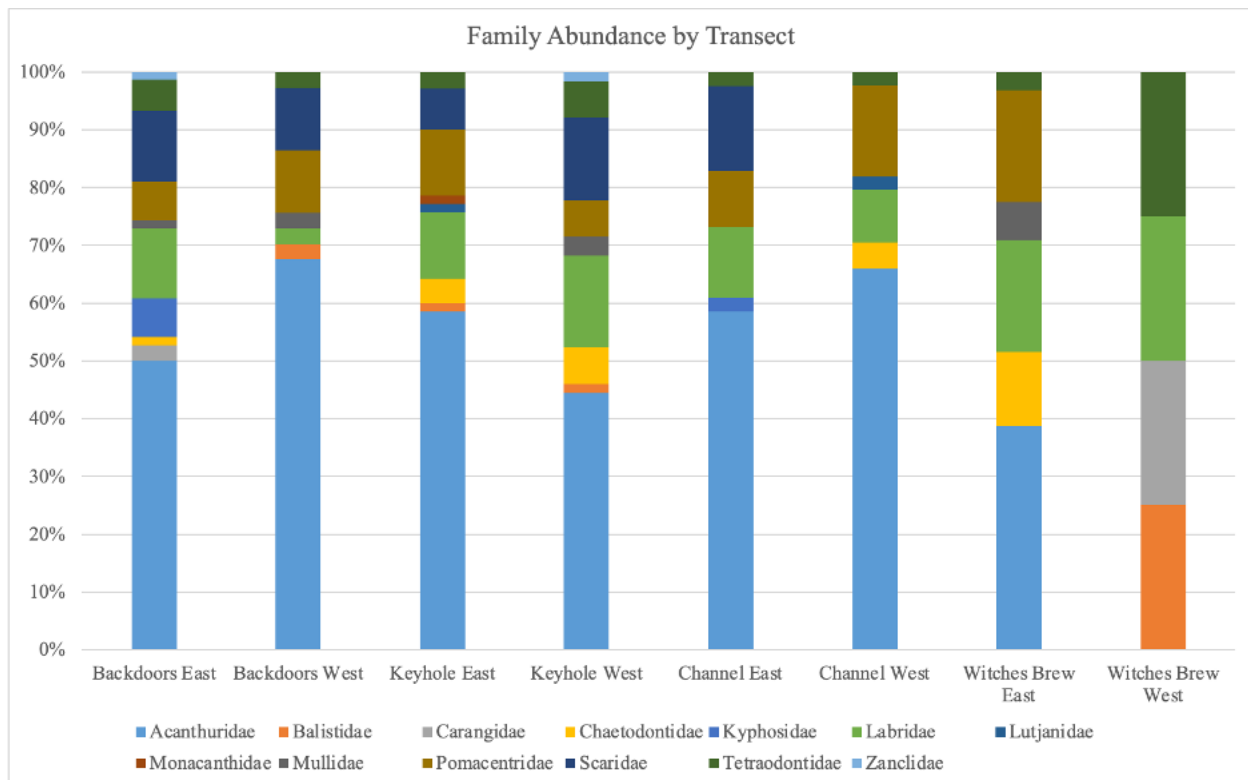


Channel (CH) had the greatest abundance of fishes ( $66.5 \pm 3.5$  individuals) when compared to the other sectors but lower biomass ( $CH: 4.71 \pm 1.06 \text{ g/m}^2$ ) than Backdoor (BD) ( $BD: 10.47 \pm 3.82 \text{ g/m}^2$ ) (Fig 9). Keyhole (KH) and Channel had similar average abundance ( $KH: 42.5 \pm 1.5$  individuals,  $BD: 55.5 \pm 18.5$  individuals), and Witches Brew (WB) had the lowest abundance and biomass ( $17.5 \pm 13.5$  individuals,  $2.01 \pm 0.68 \text{ g/m}^2$ ). BD had the highest diversity index (2.63) followed by CH (2.51) and WB (2.16) (Fig 10).



**Figure 10.** Diversity of fishes in each sector of the Hanauma Bay reef flat. The higher the diversity number the more stable the fish community.

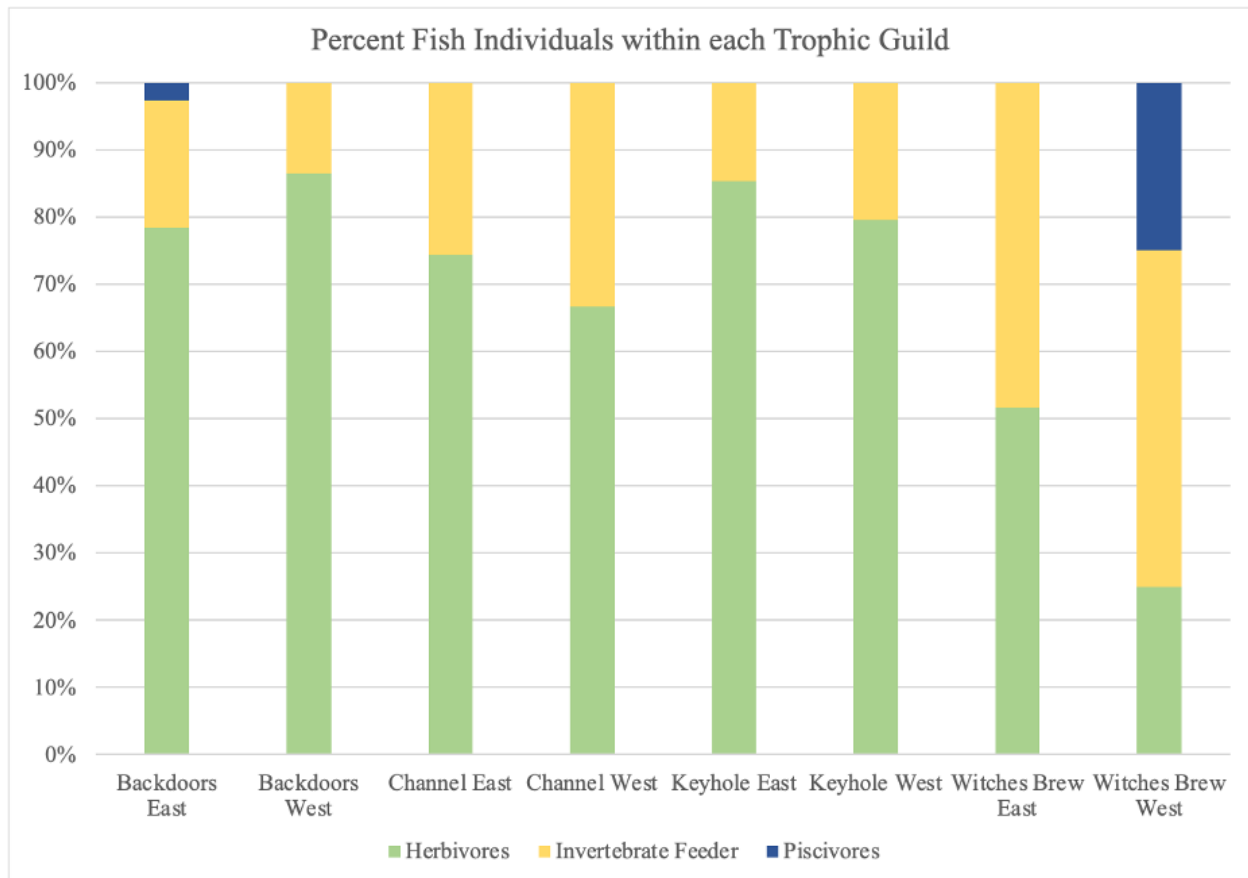
Surgeonfishes (Acanthurids) made up almost 50% of fishes on each transect. Witches Brew East had no surgeonfishes present (Fig 11).



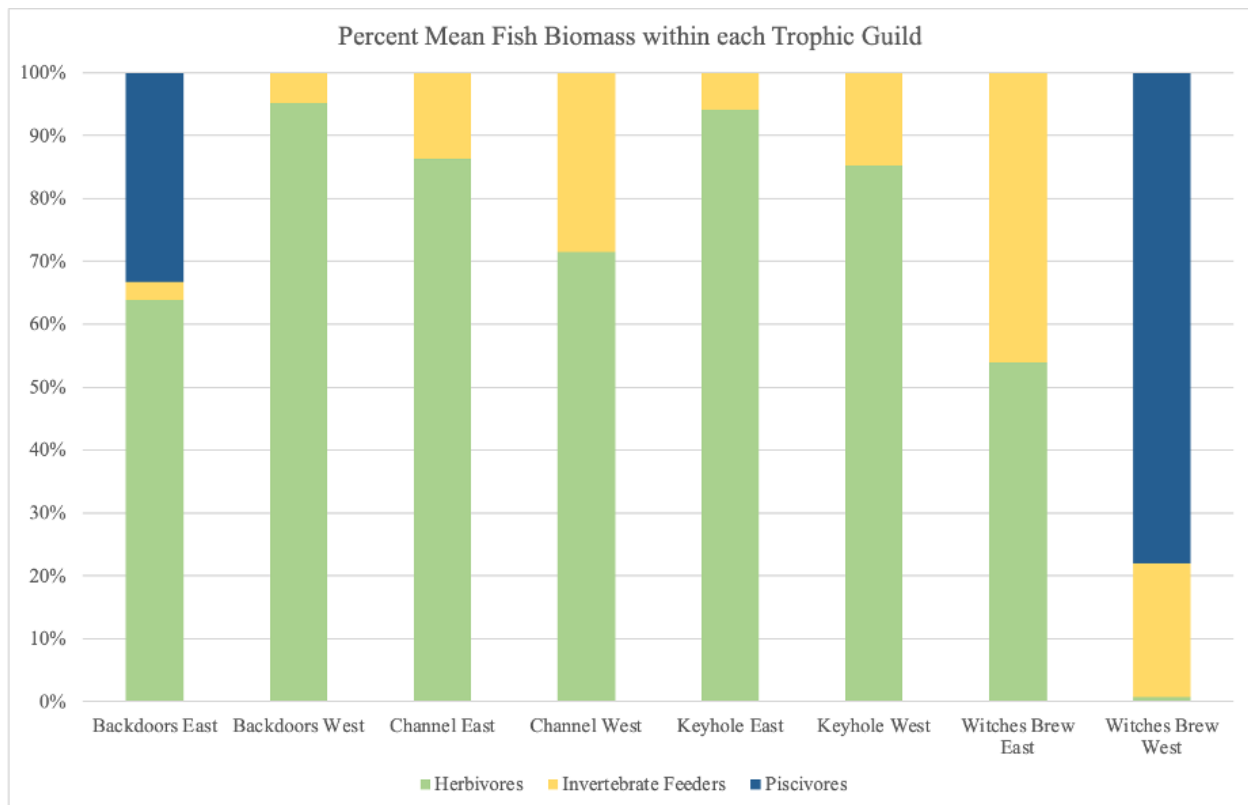
**Figure 11.** Percent individuals by family on each transect.

### Trophic Levels

Fish assemblage by trophic level was similar across all transects, with the exception of Witches Brew West. Across the inner reef flat in Hanauma Bay, herbivores make up the majority of individuals (mean: 74.6%) and biomass (mean: 78.9%), followed by invertebrate feeders (mean: 24.9%) (Figs 12 and 13). At Witches Brew West, invertebrate feeders make up the majority of abundance (50.0%), while piscivores comprise the majority of biomass (77.9%).



**Figure 12.** Percentage of individuals within each trophic guild at each transect



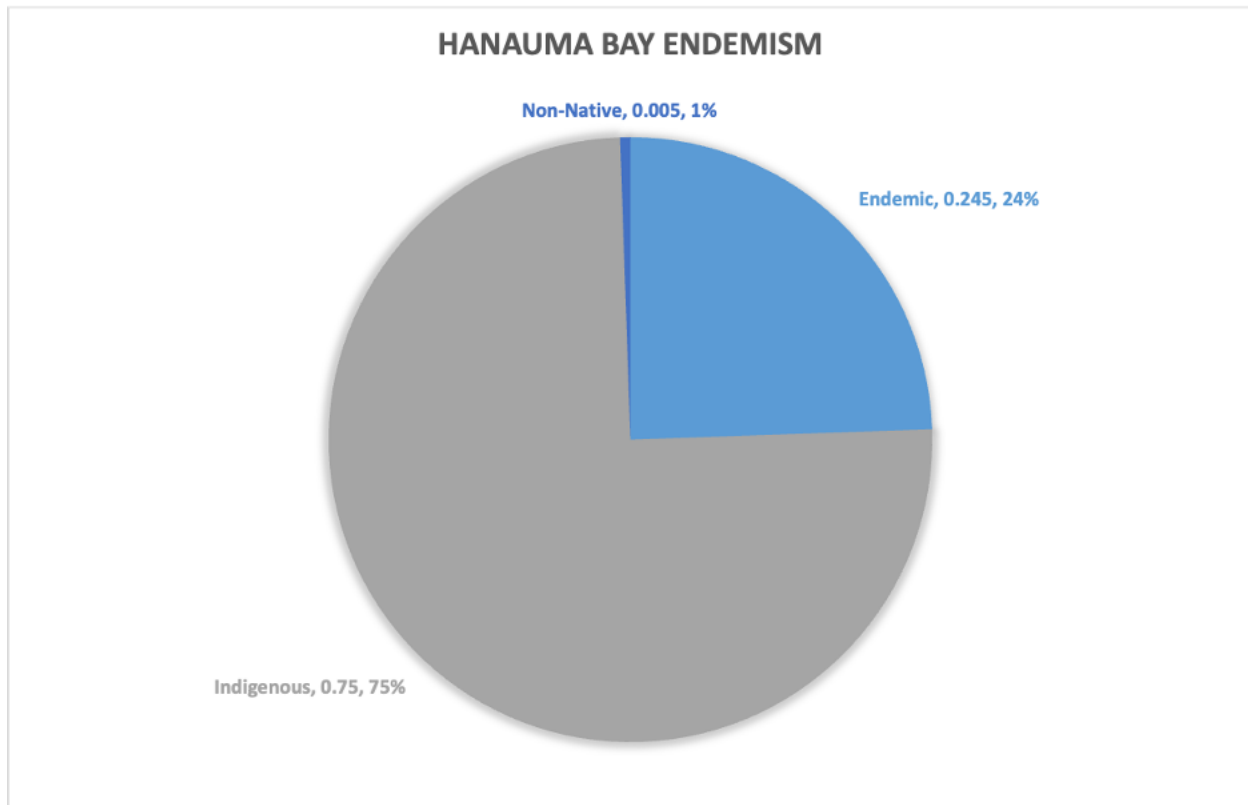
**Figure 13.** Percentage of mean fish biomass within each trophic guild at each transect.

### Endemism

At Hanauma Bay, the majority (75%) of fishes are indigenous, naturally occurring in Hawai‘i, but also found in other parts of the world. Of the remaining fishes on the inner reef flat of Hanauma Bay, 24% of fishes were endemic, found only in Hawai‘i, and 1% of individuals were non-native species (Fig 14). This is similar to the main Hawaiian Island fish endemism of 25%.

The Hanauma Bay Nature Preserve has three introduced and invasive species of fishes, *ta‘ape*, *toa‘u*, and *roi*. Introduced species have become common on reefs in the Hawaiian Islands. The Division of Aquatic Resources originally known as the Hawai‘i Fish and Game introduced three shallow water snappers from the South Pacific and Mexico in the mid-1950s and early 1960s in hopes of stimulating the commercial fisheries. These are among the 11 demersal species introduced within a 5-year period. *Lutjanus kasmira* (*ta‘ape*) the Blue-stripe snapper and *L. fulvus* (*to‘au*) the Black-tail snapper have become widely established, while the third species, *L. gibbus*, the Humpback red snapper, is extremely rare. The more common of the non-native snappers, *L. kasmira*, (*ta‘ape*) was introduced from the Marquesas in 1958, while *L. fulvus* (*to‘au*) was imported two years earlier in 1956. Although only 3,200 *L. kasmira* (bluestripe snapper, *ta‘ape*) were released on the island of O‘ahu, they have increased their range to include the entire Hawaiian archipelago. The peacock grouper *Cephalopholis argus* (*roi*) introduced by the state for commercial purposes in 1956 from Moorea, French Polynesia, originally had more popularity as a food fish than the introduced snappers. Its attractiveness as a food fish rapidly

declined as cases of ciguatera poisoning increased. This opportunistic feeder is perceived by many local fishermen as unsafe to consume and in direct competition with them because it preys upon native fish species. However, the attractive colors of the peacock grouper make it a popular snorkeler sighting.



**Figure 14.** Pie chart showing percentage of individual fish on the Hanauma Bay reef flat within each endemic status.

#### Task 4: Monk Seal and Green Turtle Abundance

Previous research conducted in Hanauma Bay Nature Preserve (HBNP) focused on documenting the abundance of monk seals (*Neomonachus schauinslandi*) and green turtles (*Chelonia mydas*), spanning three discrete time periods: in 2018 when HBNP was open to the public, during the COVID-19 closure in 2020, and following the reopening to the public at 25% capacity. The study suggested that while monk seal presence at HBNP varied in response to the closure and reopening, it was not significantly influenced by visitor numbers. Similarly, George Balazs concluded that the green turtle habitat usage did not exhibit a distinct pattern related to visitor presence. During the COVID-19 closure, Dr. Balazs also studied the relationship between Hawaiian monk seals and green turtles at the HBNP. Since his previous studies in the 1990s, Dr. Balazs has observed a decline in the number of green turtles and an increase in Hawaiian monk seals. The presence of monk seals in the Bay corresponded with a noticeable decline in the green turtle population; however, this decrease in green turtle abundance in the presence of monk seals

was not statistically significant. Given the small sample size and the limitations of anecdotal evidence, the findings regarding the interaction between green turtles and monk seals were considered preliminary.

Two female green turtles (*C. mydas*) were reported stranded at Hanauma Bay in 2019. The necropsy on these two turtles was performed by Dr. Thierry Work from the United States Geological Survey (USGS). According to the National Ocean and Atmospheric Administration (NOAA) necropsy report records, one of the turtles was “found dead then bagged by Hanauma Bay staff. Picked up by HMAR. Large hole ventral neck 9 x 6cm bite like, similar to other suspect monk seal trauma.” Dr. Balazs and community members have also witnessed green turtles being attacked or killed by monk seals in nearshore water throughout the main Hawaiian Islands. From 2009 to 2021, several green turtles were stranded across the main Hawaiian Islands. Multiple lines of evidence suggest negative interactions between monk seals and green turtles. Necropsy reports highlighted consistent trauma patterns, suggestive of predator-induced injuries. These findings differed from traditional shark-induced injuries, further pointing away from shark predation. Additionally, field reports noted similar injuries to turtles resembling monk seal trauma, reinforcing the idea that monk seals are interacting with and potentially preying on green turtles. To determine if this is occurring in Hanauma Bay, additional evidence and study are required.

During 2023, the presence of monk seals and green turtles at the HBNP were visually recorded over the span of four months. Of the six survey days, the field team observed a total of six green turtles and one monk seal in the Bay.



**Figure 15.** Green turtle with flipper bites consistent with monk seal trauma. Photo credit: NOAA

## Task 5: Coral Bleaching Surveys

Data collected in April 2023 was used to determine any bleaching prior to the annual summer temperature increases to serve as a baseline for future 2023 bleaching (Table 2). The previous survey was conducted at the same stations in March 2021. The total number of colonies in these two surveys was similar overall and at each station and (2023: 199 colonies, 2021: 220 colonies). The mean size has decreased from 25 cm in 2021 to 15 cm in 2023. Very little bleaching was detected (1.9%) while some paling was observed (12.9%). This is in agreement with temperatures that did not reach thermal coral tolerances. Backdoor had the highest level of pale (21.4%) and bleached corals (8.3%), considerably higher than other sectors (Table 2). During both 2015 and 2019 thermal stress events, Backdoors experienced the highest mortality (2015: 3.9%, 2019: 3.4%) and Keyhole experienced the lowest mortality (2015: 0.8%, 2019: 0.0%). While Channel experienced low mortality (0.3%) in 2015, during the 2019 bleaching event Channel had the highest mortality of all sectors (4.3%). Witches Brew experienced 3.2% mortality in 2015, with lower (0.5%) mortality in 2019. This may indicate an increase in survival of thermal stress with repeated exposure (Coles and Jokiel 1976, Hughes et al. 2017). Increased resiliency after a bleaching event may result from coral associated symbiont community shifts to more thermally tolerant symbionts (Baker et al. 2004, Berkelmans and van Oppen 2006) or natural selection of coral species that are more tolerant to thermal stress (Hongo and Yamano 2013, Coles et al. 2018). Bleaching prevalence can also be attributed to the resiliency of different coral species. Lace (*Pocillopora damicornis*), Ocellated (*Cyphastrea ocellina*) and Rice (*Montipora capitata*) coral were most susceptible to bleaching during the 2020 event in Hanauma Bay. Temperature stress has not been observed in 2023 as of September. November bleaching surveys will be conducted to compare with the April results. NOAA's Coral Reef Watch ([coralreefwatch@noaa.gov](mailto:coralreefwatch@noaa.gov)) has not reported or predicted any high anomalies in the main Hawaiian Islands in 2023 as of October.

**Table 2.** Coral bleaching survey summary conducted in April 2023. BD=Backdoor, KH=Keyhole, CH=Channel, WB=Witches Brew.

Site	# colonies	mean Size	Live (%)	Bleach (%)	Pale (%)	Recently Dead (%)
BD 1a	14.0	21.4	60.0	7.1	32.9	0.0
BD1b	9.0	9.0	80.6	9.4	10.0	0.0
KH 2a	16.0	9.8	84.4	5.0	10.6	0.0
KH 2b	8.0	12.3	57.5	5.0	27.5	10.0
CH 3a	17.0	26.6	98.2	0.6	1.2	0.0
CH 3b	13.0	17.5	96.9	3.1	0.0	0.0
WB 4a	46.0	14.8	61.5	0.0	34.1	3.3
WB 4b	76.0	11.6	99.5	0.3	0.3	0.0
# colonies	199.0	15.4	79.8	3.8	14.6	1.7
site mean	24.9	15.4	79.8	3.8	14.6	1.7
overall mean		14.5	83.9	1.9	12.9	1.2

### Task 6: Species Archive

The archive consists of three sections, each serving as a valuable resource for visitors to the HBNP. The Master Species Document encompasses a list of species found in the Bay, while separate links cater to those interested in fishes, invertebrates, or seaweeds. The Fish Photo Archive offers a collection of fish species found in the Bay, complete with photos, detailed descriptions, and common, scientific, and Hawaiian names. Additionally, it provides links to external websites with a broader range of fish images, including juveniles, adults, and sexually dimorphic fishes. Similarly, the Invertebrate Photo Archive presents a user-friendly chart showcasing invertebrate species with accompanying photos, descriptions, and naming conventions, along with external links for more diverse image references. The Limu Species List Photo Archive compiles a list of macroalgal species observed at Hanauma Bay. Together, these archives offer visitors an informative and visually engaging tool for understanding and identifying the diverse marine life at the HBNP. This archive is intended to provide an additional resource for visitors to the HBNP website.

### **Links to the Archives**

[Master Species Doc Link](#)

[Fish Archive Link](#)

[Invertebrate Archive Link](#)

[Limu Archive Link](#)



Websites referenced for photos and information:

<https://www.marinelifephotography.com/>

<https://www.algaebase.org/>

<https://coe.hawaii.edu/opihi/orgcategory/algae/>

<http://www.coralsoftheworld.org/page/home/>

<http://www2.bishopmuseum.org/>

<https://www.fishbase.se/search.php>

<https://www.sealifebase.ca/>

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